TNO Defence Research

TD 93-2536

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TNO-report: **IZF 1993 B-15**

J. Theeuwes

TEMPORAL AND SPATIAL CHARACTERISTICS OF PREATTENTIVE AND ATTENTIVE PROCESSING

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Number of pages: 17

Netherlands organization for applied scientific research

TNO Defence Research consists of the TNO Physics and Electronics Laboratory, the TNO Prins Maurits Laboratory and the TNO Institute for Human Factors

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Title:	Temporal and spatial characteristic of preattentive and attentive processing
Author:	Dr.Ing. J. Theeuwes
Institute:	TNO Institute for Human Factors Group: Skilled Behaviour
Date:	November 1993
DO Assignment No.:	B92-28
No. in Program of Work:	788.2

SUMMARY

In the present experiment, subjects searched multi-element displays for a color singleton. With a variable display-to-onset interval, on some trials an abrupt onset was presented at three possible distances from the target location. The interference effect caused by the abrupt onset as a function of SOA and its relative position revealed the distinctive characteristics of pre-attentive and attentive processing. During preattentive parallel processing (processing occurring within the first 100 ms), any abrupt onset that occurred within the visual field captured attention. During attentive processing (processing occurring after 100 ms), however, focussed attention precluded the capturing of attention of the abrupt onset. The finding that abrupt onsets interfere with selective search for a color singleton provides additional evidence for the notion of inadequate top-down control at the level of preattentive processing.

Rap.nr. IZF 1993 B-15 Instituut voor Zintuigfysiologie TNO
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Temporele en spatiële eigenschappen van preattentieve en attentieve verwerking

J. Theeuwes

SAMENVATTING

In dit experiment dienden proefpersonen op een beeldscherm te zoeken naar een element met een unieke kleur. Tijdens een aantal trials werd er met een variabel interval een element met een "abrupte onset" toegevoegd aan het display. De verstoring die dit element met "abrupte onset" veroorzaakte, gaf de eigenschappen weer van respectievelijk preattentieve en attentieve verwerking. Gedurende preattentieve parallelle verwerking (verwerking die plaatsvindt gedurende de eerste 100 ms) gaf de abrupte onset een verstoring ongeacht waar in het visuele veld de abrupte onset verscheen. Gedurende attentieve verwerking (verwerking die plaatsvindt na 100 ms), leidde het richten van aandacht naar een plaats in het visuele veld ertoe dat de abrupte onset geen aandacht meer trok. De bevinding dat abrupte onsets het zoeken naar een unieke kleur verstoren, geeft additionele evidentie voor het idee dat er onvoldoende top-down controle is gedurende preattentieve parallelle verwerking.

1 INTRODUCTION

Most current accounts of human vision suggest that there are two distinguishable and functionally distinct forms of visual information processing (e.g., Broadbent, 1958, 1982; Neisser, 1967; Treisman & Gelade, 1980). One form is typically characterized as being *preattentive* which implies an unlimited-capacity system capable of spatial parallelism in information processing. The other form is termed *attentive* (focal) processing because it requires the allocation of attentional resources to a location in visual space. This latter system has a limited capacity and processes information serially.

It is generally assumed that in visual search, these two processes operate sequentially: preattentive processes perform some basic analyses segmenting the visual field into functional perceptual units, followed by the attentive stage which deals with one (or a few) item at a time. The present study investigates the characteristics of the allocation of attention in visual space following preattentive parallel processing.

Yantis and Johnston (1990) suggested a "variable locus" hypothesis in which people have the flexibility to have either an early locus for selective attention under focussed attention tasks in which it is desirable to minimize processing of to-be-ignored items or a late locus under divided attention tasks in which it is desirable to process all items intensively. A similar notion was put forward by Kahneman and Treisman (1984) who made a distinction between attentional systems described as *set* (divided attention) and *filtering* (focussed attention). The present study explores the hypothesis that both types of selection occur sequentially in visual search for feature singletons: the early preattentive stage has the characteristics of a divided attentional system whereas the later, attentive stage has the characteristics of a focussed attentional system.

As suggested by Kahneman and Treisman (1984) divided attention tasks show a remarkable ability to process multiple stimuli. Typically, in visual search tasks, targets defined by some primitive feature such as color, shape, brightness are detected equally fast, irrespective of the number of elements in the display (e.g., Egeth, Jonides & Wall, 1972; Treisman & Gelade, 1980). This finding suggests that the processing of the display elements is performed in parallel over the entire display. The type of processing is attributed to the early preattentive processing stage.

As recognized by Kahneman & Treisman (1984) divided attention experiments in which multiple stimuli are processed simultaneously typically show the *un*successful attempt of subjects to resist distraction. Feature registration at the preattentive stage is thought to occur automatically (Treisman & Schmidt, 1982). Theeuwes (1991a, 1992 in press a) demonstrated both effects: in visual search tasks, the time to detect a featural singleton (i.e., search for a red item among green nontarget items) did not depend on display size suggesting preattentive parallel search. Yet, under these circumstances, subjects did not have the ability

to resist distraction: an irrelevant featural singleton in a dimension different from the relevant one, disrupted performance.

Theeuwes (1991a, 1992, in press a, in press b) concluded that in tasks in which subjects divide attention in order to detect the featural singleton in parallel, subjects do not have the ability anymore to control what objects are selected for further processing. In other words, the ability to process several stimuli simultaneously has the consequence that top-down selectivity is lost (see also, Theeuwes, 1993). These findings have led to the conjecture that there is no top-down control at the level of preattentive processing. When using the preattentive parallel search mode, the extent to which singletons capture attention is determined by the relative saliency of the singletons present in the visual field. Irrespective of what subjects are looking for (i.e., irrespective of any top-down control), spatial attention is automatically and involuntary captured by the most salient singleton (for an extensive review, see Theeuwes, in press b).

On the other hand, focussed attention experiments show the remarkable ability of subjects to focus attention efficiently on the relevant stimuli only without any interference of the 'unattended' stimuli (Kahneman & Treisman, 1984). Attention is thought to operate like a spatial filter assuming that inside the focus of attention everything is attended while outside the focus everything is unattended (Yantis & Johnston, 1990). This has led to the conceptualization of visual attention as something like a spotlight (e.g., Posner, 1980; Broadbent, 1982), or a zoom-lens (e.g., Eriksen & Yeh, 1985).

Yantis and Jonides (1990) and Theeuwes (1991b) showed the ability of spatial attention to filter out irrelevant singletons. When search was eliminated by cuing with absolute certainty the spatial location of the impending target, onset and offset singletons elsewhere in the visual field did not affect performance. It was concluded that abrupt onsets and offsets ceased to capture attention because focussing of attention on a particular location blocks out information from elsewhere in the visual field.

Theeuwes (1991a, 1992, in press a, in press b) suggested that top-down selection can only operate *spatially*, that is, the only strategic control over visual selection is through varying the span of spatial attention in the visual field. If attention is spread out over the visual field (the divided attention mode), it is possible to process multiple stimuli at the expense of losing selectivity within that area. If attention is focussed on a restricted area (the focussed attention mode), processing has to occur serially; yet, then it is possible to filter out stimuli located outside the attended area.

It is hypothesized that the two sequential processes, i.e., preattentive parallel and attentive serial processing, occurring during visual search for feature singletons have the properties of *divided* and *focussed* attention, respectively. Preattentive processing should show the ability to process multiple stimuli at the same time, that is, the featural singleton should be detected irrespective of the number of

elements in the display. In addition, because processing occurs in parallel (divided attention), at this stage, top-down selectivity is not possible. Irrelevant featural singleton will disrupt search for the relevant target singleton.

It is presumed that stimuli entering the second stage of attentive processing are selected for further processing. The basis of selection is thought to be spatial, that is, during the second stage of attentive processing attention is spatially allocated to the location of a featural singleton. Consequently, because attention is now focussed on a location, the attentional system should have the properties of a filtering mechanism. Stimuli well outside the focus of attention should not affect performance. If this filtering occurs spatially then it is expected that the efficiency of filtering depends on the distance between target and interfering stimulus (Yantis & Johnston, 1990).

The task used in the present study was similar to the task used by Theeuwes (in press a). Subjects had to search for a color singleton embedded among 2 or 5 nontarget items in the visual field (a grey circle embedded among red circles). On some trials another location contained an irrelevant onset (i.e., a red circle presented with abrupt onset). The distance between the grey target circle and the irrelevant abrupt onset was systematically varied. In addition, the interval between search display and irrelevant abrupt onset was systematically varied (display-to-onset Stimulus Onset Asynchrony of 0, 50, 100, and 150 ms).

Theeuwes (in press a) showed that in a similar task, selective search for a color singleton was disrupted when an irrelevant abrupt onset was presented simultaneously with the color target singleton. Those results provided evidence that salient abrupt onsets will capture attention irrespective of the attentional set of the observer. The present experiment uses the disruption of performance caused by the abrupt onset as a tool to assess the characteristics of preattentive and attentive processing.

If preattentive and attentive serial processing have the properties of *divided* and *focussed* attention several results are expected. First, if the abrupt onset is presented during preattentive processing, then it is expected that the interference caused by the onset is independent of the distance between target and onset. Because attention is divided over the visual field, onsets from any location within the attended area will attract attention. Second, if the abrupt onset is presented during attentive processing, then it is expected that onsets close to the location of the target singleton will disrupt performance while onsets further away from the target location will not affect performance anymore. This latter result is expected given the conjecture that the second stage of attentive processing entails the allocation of attention to the location of featural singleton. Stimuli close to the focus of attention will interfere while stimuli away from the focus of attention will not affect performance. Since it is unclear how long preattentive processing takes, the exact time course of the predicted effects is unclear. The only plausible hypothesis which can be inferred is that at SOA 0 ms preattentive

processing is in operation, while at SOA 150 ms attentive processing is (most likely) in operation.

2 METHOD

2.1 Subjects

Eight right-handed subjects, ranging in age from 18 to 28 years, participated as paid volunteers. All had normal or correct-to-normal vision and reported having no color vision defects.

2.2 Apparatus and Stimuli

A NEC Multisync 3D VGA color CRT (resolution 640x350) controlled by a SX-386 Personal Computer (G2) was used for presenting the stimuli. The computer using the Micro Experimental Laboratory software package controlled the timing of the events, generated pictures and recorded reaction times. The '/'-key and the 'z'-key of the computer keyboard were used as response buttons. Each subject was tested in a sound-attenuated, dimly-lit room, his head resting on a chinrest. The CRT was located at eye level, 115 cm from the chinrest.

The display elements consisted of grey (CIE x,y chromaticity coordinates of .283/.341) or red (coordinates of .408/.397) outline circles which were matched for luminance (10.1 cd/m^2). The fixation cross and the line segments were presented in white (31.0 cd/m^2) on a black background (0.5 cd/m^2). The colorimetric and photometric measurements were carried out by means of a spectro-radiometer (Photo Research, type: PR 703 A/M). The detector head of this device was directed towards color patches displayed at the center of the computer screen.

2.3 Procedure

The task was similar to that in Theeuwes (1991b, 1992), consisting of a visual search task in which there is a clear separation between the defining and reported attribute of the target. Subjects responded to the orientation (horizontal or vertical) of a line segment appearing inside a grey circle embedded among red circles. Because subjects responded to the orientation of a target line segment located among slightly tilted nontarget line segments, the task required focal attention (Theeuwes, 1991b; Treisman & Gormican, 1988) but not a high spatial acuity. The onset stimuli were constructed similar to Theeuwes (in press a), in which onset stimuli were presented in previously blank locations, and no-onset stimuli were camouflaged by premasks.

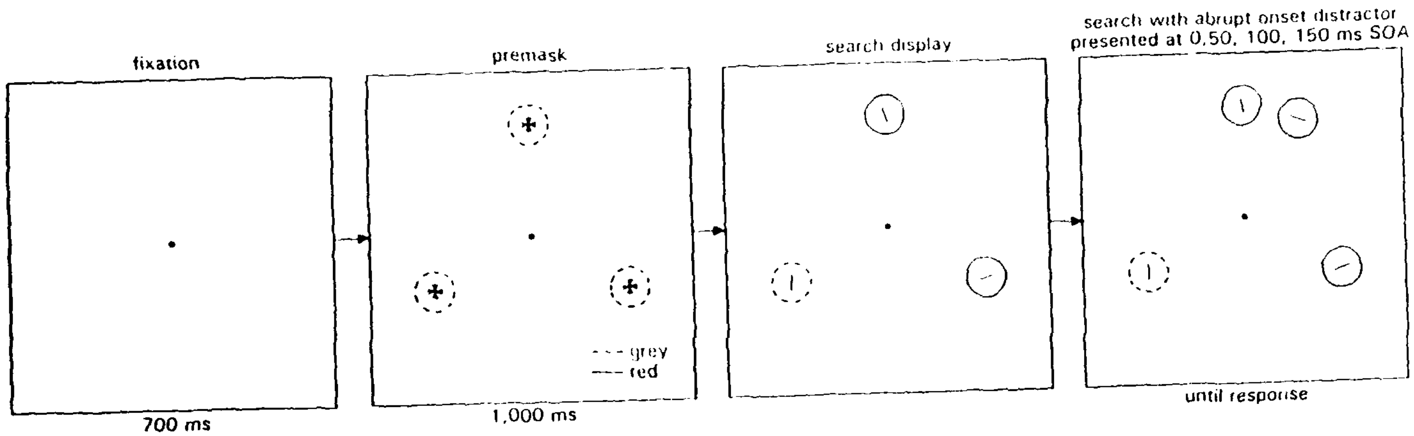


Fig. 1 Trial events in which subjects search for a uniquely colored grey circle (In this example, the distractor is an irrelevant circle with abrupt onset presented 150 degrees of arc from the grey target circle. The abrupt onset is presented with variable display-to-onset SOAs, the target line segment is vertical and located in the uniquely colored grey circle).

The trial events are shown in Figure 1. At the beginning of a trial a central dot appeared, upon which subjects remained fixated throughout a trial. After 700 ms, a premask was presented consisting of three or six grey outline circles (1.2° of diameter) which were equally spaced around the fixation point on an imaginary circle whose radius was 3.4°. The six circles formed a hexagon; the three circles formed either a upward-pointing or downward-pointing equilateral triangle. Each circle contained six line segments (0.5°), one vertical, one horizontal and four tilted 20° to either side of the horizontal and vertical plane. After 1,000 ms premask the stimulus field was presented. At the end of the 1,000-ms premask period, 5 of the 6 line segments in each of the circles were extinguished, revealing line segments that were tilted 20° to either side of the horizontal or vertical plane. The orientations were randomly distributed in a display. In only one circle, the extinguished line segments revealed a line segment oriented either horizontally or vertically; the orientation determined the appropriate response key (the '/'-key for vertical and the 'z'-key for horizontal). At the end of the 1,000-ms premask period, the color of all circles except the circle containing the target line segment changed into equiluminant red. The one circle that remained grey contained the horizontal or vertical target line segment. In the distractor condition, at the end of the 1,000-ms premask period, a circle having the same red color as the other nontarget circles was presented at one of the 6 previously blank locations of the 3.4° imaginary circle. In the control condition, in which no circle with abrupt onset was presented, an additional nontarget circle was presented, along with the premask, at one of the blank locations at the beginning of the premask period. The stimulus field remained present for a maximum of 2 s until a response was emitted.

Subjects received two conditions: (1) a control condition in which the grey circle containing the target line segment was presented with 3 or 6 red circles, and (2) a distractor condition in which one of the 3 or 6 red circles had abrupt onset. These abrupt onsets were presented with four possible display-to-onset SOAs; 0, 50, 100, or 150 ms which were varied within blocks of trials. The abrupt onset in the distractor condition and the additional circle in the control condition were presented at 3 possible distances from the grey target circle. On the imaginary circle with the fixation dot as its center, the abrupt onset was presented next to the target describing an angle between target and distractor of 30 degrees of arc, somewhat further away from the target describing an angle at 90 degrees of arc, or presented almost opposite of the target describing an angle of 150 degrees of arc. In euclidian distances, these figures correspond to 2.0°, 5.0°, 7.1° of visual angle, respectively. This factor was varied within blocks of trials. As will be clear, when searching for a uniquely colored grey circle, the distracting element was a red circle with abrupt onset which was presented simultaneously (at SOA 0 ms) or slightly later than the search display (at SOA 50, 100, 150 ms). The grey target circle was presented equally often at each location. The location was randomized from trial to trial. It replaced always one of the circles from the premask display. The position of the onset circle was randomized as well, yet it was presented equally often at one of the six blank locations.

There were three blocks of 288 trials in the distractor condition and one block of 288 trials in the control condition. Each subject performed both distractor and the control conditions. Half of the subjects started with the distractor condition, the other half with the control condition. The practice session consisted of 72 distractor and 72 control trials. Display size (4,7) was randomized within blocks. In the distractor condition subjects performed 864 trials that is, a total of 36 trials in each display size (4,7), distance (30, 90, 150 degrees of arc) and SOA (0, 50, 100, 150 ms) condition. In the control condition, subjects performed a total of 288 trials, that is, a total of 48 trials in each display size (4,7) and distance (30, 90, 150 degrees of arc) condition.

Each block of trials lasted approximately 20 minutes, followed by a 20 minutes break. Within each block, there were short breaks after 72 trials in which subjects received feedback about their performance (percentage errors and mean reaction time) on the preceding block of trials. Prior to the start of the experiment subjects were instructed to search for the horizontal or vertical target line segment and to press the appropriate response key with one of their index fingers which were resting on '/' and 'z'-keys. Before each session, the subjects were informed about the relationship between the location of the target line segment and the unique display element: subjects were told that the target line segment was always located in the uniquely colored grey circle. They were instructed to use this information. It was emphasized that subjects should fixate the central dot and not move their eyes during the course of any trial. It was stressed that a steady fixation would reduce reaction time (RT) and make the task easier. Both speed and accuracy were emphasized. A warning beep informed subjects that an error had been committed. If no response was made after 2 s, subjects were informed that they had committed an error.

3 RESULTS

Response times longer than 1 s were counted as errors, which led to a loss of about 1.9% of the trials. The data of control and distractor conditions were subjected to separate ANOVAs. The distractor condition, using distance (30, 90, 150 degrees of arc), display size (4,7) and SOA (0, 50, 100, 150 ms) as factors, showed main effects on RT for distance, display size and SOA [$F(2,14)=35.2$; $p<.01$, for distance, $F(1,7)=23.0$; $p<.01$ for display size, and $F(3,21)=18.5$; $p<.01$ for SOA]. Also, the interaction between distance and SOA was significant [$F(6,42)=4.9$; $p<.01$]. The control condition, using distance (30, 90, 150 degrees of arc) and display size (4,7) as factors, showed main effects on RT for both distance and display size [$F(2,14)=8.5$; $p<.01$, for distance, and $F(1,7)=69.1$; $p<.01$ for display size]. Planned comparisons show that, in the control condition, the presence of an item close to the target item (i.e., at 30 degrees of arc) gives reliably longer RTs than when this item is located at a position further away from the target item (i.e., for 90 degrees of arc [$F(1,7)=10.3$; $p<.05$] and for 150 degrees of arc [$F(1,7)=10.3$; $p<.05$], respectively). There is no difference

between these latter RTs. Figure 2 gives the mean RTs for distractor and control conditions collapsed over display size.

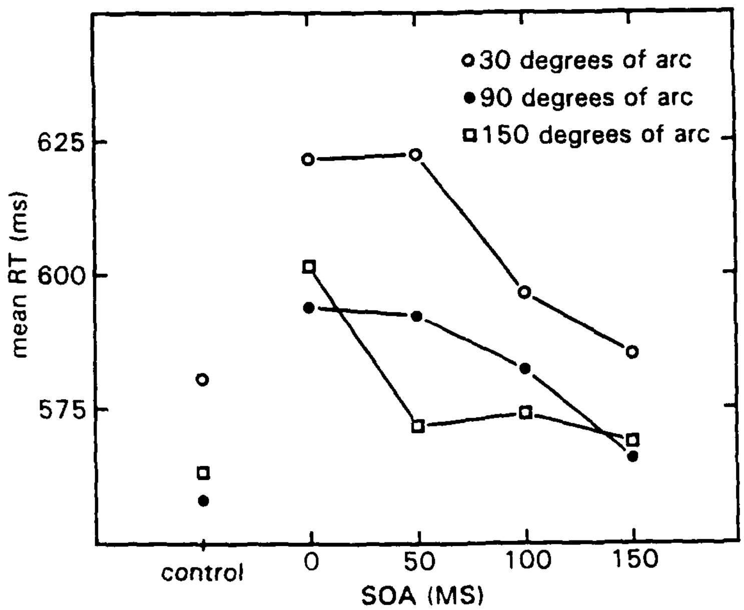


Fig. 2 Mean reaction time for search for a color singleton as a function of display-to-onset distractor SOA for the different distances (30, 90, 150 in degrees of arc) between the target color singleton and the onset distractor.

For each distance, the distracting effect of the onset for each SOA was calculated relatively to its own control (see Table I). The results of subsequent planned comparisons are indicated in Table I. As is clear from Table I relative to the control condition, for each distance at SOA 0 ms, there is a reliable distracting effect. In addition, at SOA 0 ms, the distracting effect caused by the onset is the same for all distances between target and distractor [$F(2,14)=.21$]. At SOA 50 ms, the onset 150 degrees of arc away from the target item does not cause any interference any more. Onsets at 30 and 90 degrees of arc away from the target item still give a reliable distracting effect. There is no difference in distracting effect between an onset at 30 and 90 degrees of arc [$F(1,7)=.93$]. At SOA of 100 and 150 ms there is no reliable effect anymore of the onsetting item.

Table I Error Rates (in Percent) for each distance (degrees of arc) between target item and distractor for both the control and the distractor condition and each SOA.

distance	control	SOA			
		0	50	100	150
30 degrees	5.47	8.88	6.60	6.08	5.38
90 degrees	3.78	5.73	7.46	5.55	3.30
150 degrees	2.86	5.03	6.60	5.21	4.68

Table II Distracting effect calculated relative to the control condition for each distance between target item and distractor (degrees of arc) as a function of SOA of abrupt onset. Asterisks indicate whether the effect differs significantly from the control condition.

distance	distracting effect (ms) SOA			
	0	50	100	150
30 degrees	41**	43*	16	6
90 degrees	36*	34*	25	8
150 degrees	39**	9	11	6

** p < 0.01
* p < 0.05

Error rates are shown in Table II. Overall, the error rate was 5.9% for the distractor condition and 4.0% for the control condition. In order to achieve homogeneity of the error-rate variance, the mean error rates per cell were transformed by means of an arcsine transformation. The same planned comparison as performed on the RT data show that relative to the distractor condition at SOA 0 ms and SOA 50 ms significantly less errors are made in the control condition when the distractor is located 150 degrees of arc away from the target (for SOA 0 ms [$F(1,7)=8.8$; $p<.05$] and for SOA 50 ms [$F(1,7)=27.6$; $p<.05$], respectively). In addition, relative to the distractor condition at SOA 50 ms significantly less errors are made in the control condition when the distractor is located 90 degrees of arc away from the target [for SOA 50 ms [$F(1,7)=6.2$; $p<.05$]. As this analysis indicates that error differences are non-significant or tend to mimic RT, differences in response cannot be attributed to a speed-accuracy trade-off.

In order to check whether parallel search across all items occurred, the RTs collapsed over distance and SOA were submitted to a linear regression analysis. The mean slopes for the distractor and control condition were 8.5 and 8.6 ms/item, respectively. Both slopes were small (less than 10 ms/item) and in the

range generally assumed to reflect parallel processing (Treisman & Gormican, 1988).

4 DISCUSSION

The present experiment provides independent evidence for the notion that visual information processing consists of two functionally independent processes: an early pre-attentive parallel process segmenting the visual field into basic units followed by an attentive process involving focal attention that operates on one (or a few) item at a time. The interference effect caused by the abrupt onset as a function of SOA and relative position reveals the distinctive characteristics of these two processes (see Table I). At SOA 0 ms, attention is divided over the visual field in order to allow the parallel detection of the uniquely color singleton. In this mode of parallel processing, any abrupt onset occurring within the attended field captures attention automatically and unintentionally causing an inference effect that does not dependent on the position of the abrupt onset relative to the target position. It is assumed that attention is then switched to the target location in order to respond to the line segment located in the uniquely colored singleton. In line with earlier research (i.e., Kwak, Dagenbach & Egeth, 1991; Sagi & Julesz, 1985), it is assumed that shifting attention from the location of the abrupt onset to the location of the target is thought to occur time-independently suggesting that attention can index locations in the visual field that is independent of the distance between these locations (Eriksen & Webb, 1989).

At SOA 50 ms it is likely that focal attention has started to zoom in at the location of the uniquely colored singleton. Because attention is not yet highly focussed on the location of the uniquely colored singleton, abrupt onsets presented relatively close to the singleton (distances of 30 and 90 degrees of arc) fall within the attended area, and therefore can cause interferencc. The abrupt onset farthest away from the singleton (at 150 degrees of arc), does not affect performance anymore because it falls outside attended area.

At SOA 100 and 150 ms it is assumed that attention is fully and highly focussed on the location of the singleton, preventing attentional capture by onsets outside the attended area. This suggests that the process involving the parallel segmentation of the visual field and the subsequent zooming-in on the location of the uniquely colored singleton, takes somewhere between 50 and 100 ms.

The observed pattern of results provides evidence for the notion that preattentive and attentive processing have the characteristics of divided and focussed attention, respectively. In order to detect the uniquely colored singleton preattentively and in parallel, attention has to be divided over the visual field (unfocussed attention) at the expense of losing selectively within that area. Irrespective of the attentional set of the observer (i.e., subjects were looking for a uniquely colored singleton), the abrupt onsets captured attention and disrupted

search for the task-relevant singleton, results confirming earlier findings (Theeuwes, 1991a, 1992, in press a). At the second stage of processing, when attention operates in its focussed mode encompassing the uniquely colored singleton, attention operates like a spatial filter blocking out all information outside the attended (spotlight) of attention.

The notion that focussing attention can operate as a spatial filter is supported by cuing studies showing that when subjects endogenously focus their attention on a cued location, irrelevant abrupt onsets and offsets presented elsewhere in the visual field do not capture attention anymore (Yantis & Jonides, 1990; Theeuwes, 1991b). This interpretation suggests that attentive processing occurring during visual search is equivalent to directing spatial attention as occurring in location cuing experiments (see also Theeuwes, in press b).

The present study replicates findings of an earlier study (Theeuwes, in press a) which showed that search for a uniquely colored singleton was disrupted when an irrelevant onset was presented simultaneously (the present SOA 0 ms condition) with the color target singleton. Theeuwes' previous study (in press a) tested the contingent capture hypothesis which claimed that the occurrence of attentional capture is contingent on the attentional control setting induced by the task demands (Folk, Remington & Johnston, 1992). In Folk et al.'s experiments, subjects had to ignore cues immediately prior to the presentation of the target display. It was demonstrated that an onset singleton serving as a cue, did not capture attention when observers adopted an attentional set for color singleton targets. On the other hand, when observers were set to identify a color singleton with a color singleton serving as a cue, time to identify the color singleton increased, suggesting that subjects could not ignore another color singleton (the cue) known to be irrelevant. Folk et al. (1992) claim that these findings suggest that capture of attention was contingent on top-down control settings. Theeuwes (in press a) and the present study show that the contingent capture hypothesis does not hold: independent of the attentional set of the observer (i.e., subjects searched for a unique color singleton) attention was captured by the irrelevant onset distractor. Note that the present study indicates that attention can be shifted rapidly between distractor and target locations when these locations contain elements consisting of different stimulus dimensions (i.e., color and abrupt onset). As noted earlier (Theeuwes, in press a), rather than showing that attentional capture is contingent on internal control setting, Folk et al.'s (1992) study might reveal difficulties in disengagement of attention from the cue location to target location when target and distractor share the same target defining property (i.e., searching for a unique color with a cue that contains a unique color as well).

REFERENCES

Broadbent, D.E. (1958). *Perception and communication.* London: Pergamon.

Broadbent, D.E. (1982). Task combination and the selective intake of information. *Acta Psychologica* 50, 253-290.

Egeth, H., Jonides, J. & Wall, S. (1972). Parallel processing of multielement displays. *Cognitive Psychology* 3, 674-698.

Eriksen, C.W. & Webb, J.M. (1989). Shifting of attentional focus within and around the visual field. *Perception & Psychophysics* 45, 175-183.

Eriksen, C.W. & Yeh, Y.Y. (1985). Allocation of attention in the visual field. *Journal of Experimental Psychology: Human Perception and Performance* 11, 583-597.

Folk, C.L., Remington, R. & Johnston, J.C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance* 18, 1030-1044.

Kahneman, D. & Treisman, A. (1984). Changing views of attention and automaticity. In R. Parasuraman & D.R. Davies (Eds), *Varieties of Attention* (pp. 29-61). New York: Academic Press.

Kwak, H., Dagenbach, D. & Egeth, H. (1991). Further evidence for a time-independent shift of the focus of attention. *Perception & Psychophysics* 49, 473-480.

Neisser, U. (1967). Cognitive Psychology. New York: Appleton-Century-Crofts.

Posner, M. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology* 32, 3-25.

Sagi, D. & Julesz, B. (1985). "Where" and "what" in vision. *Science* 228, 1217-1219.

Theeuwes, J. (1991a). Exogenous and endogenous control of attention: The effect of visual onsets and offsets. *Perception & Psychophysics* 49, 83-90.

Theeuwes, J. (1991b). Cross-dimensional perceptual selectivity. *Perception & Psychophysics* 50, 184-193.

Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & Psychophysics* 51, 599-606.

Theeuwes, J. (1993). Visual selective attention: a theoretical analysis. *Acta Psychologica* 53, 93-154.

Theeuwes, J. (in press a). Stimulus-driven capture and attentional set: Selective search for color and visual abrupt onset. *Journal of Experimental Psychology: Human Perception and Performance.*

Theeuwes, J. (in press b). Endogenous and exogenous control of visual attention. *Perception.*

Treisman, A.M. & Gelade, G. (1980). A feature integration theory of attention. *Cognitive Psychology* 12, 97-136.

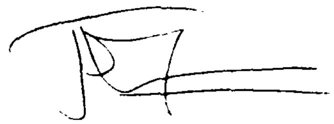
Treisman, A.M. & Gormican, S. (1988). Feature search in early vision: Evidence from search asymmetries. *Psychological Review* 95, 15-48.

Treisman, A.M. & Schmidt, N. (1982). Illusory conjunctions in the perception of objects. *Cognitive Psychology* 14, 107-141.

Yantis, S. & Johnston, J.C. (1990). On the locus of visual selection: Evidence from focused attention tasks. *Journal of Experimental Psychology: Human Perception and Performance* 16, 135-149.

Yantis, S. & Jonides, J. (1990). Abrupt visual onsets and selective attention: Voluntary versus automatic allocation. *Journal of Experimental Psychology: Human Perception and Performance* 16, 121-134.

Soesterberg, November 26, 1993



Dr.Ing. J. Theeuwes

REPORT DOCUMENTATION PAGE

1. DEFENCE REPORT NUMBER (MOD-NL)	2. RECIPIENT'S ACCESSION NUMBER	3. PERFORMING ORGANIZATION REPORT NUMBER
TD 93-2536		IZF 1993 B-15
4. PROJECT/TASK/WORK UNIT NO.	**5. CONTRACT NUMBER**	**6. REPORT DATE**
788.2	B92-28	26 November 1993
7. NUMBER OF PAGES	**8. NUMBER OF REFERENCES**	**9. TYPE OF REPORT AND DATES COVERED**
17	22	Final

10. TITLE AND SUBTITLE

Temporal and spatial characteristic of preattentive and attentive processing

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14. SUPPLEMENTARY NOTES

15. ABSTRACT (MAXIMUM 200 WORDS, 1044 BYTE)

In the present experiment, subjects searched multi-element displays for a color singleton. With a variable display-to-onset interval, on some trials an abrupt onset was presented at three possible distances from the target location. The interference effect caused by the abrupt onset as a function of SOA and its relative position revealed the distinctive characteristics of pre-attentive and attentive processing. During preattentive parallel processing (processing occurring within the first 100 ms), any abrupt onset that occurred within the visual field captured attention. During attentive processing (processing occurring after 100 ms), however, focussed attention precluded the capturing of attention of the abrupt onset. The finding that abrupt onsets interfere with selective search for a color singleton provides additional evidence for the notion of inadequate top-down control at the level of preattentive processing.

16. DESCRIPTORS	IDENTIFIERS
Reaction Time Search Vision	

17a. SECURITY CLASSIFICATION (OF REPORT)	17b. SECURITY CLASSIFICATION (OF PAGE)	17c. SECURITY CLASSIFICATION (OF ABSTRACT)

18. DISTRIBUTION/AVAILABILITY STATEMENT	17d. SECURITY CLASSIFICATION (OF TITLES)
Unlimited availability	

VERZENDLIJST

1. Hoofddirecteur van TNO-Defensieonderzoek

2. Directie Wetenschappelijk Onderzoek en Ontwikkeling Defensie

3. { Hoofd Wetenschappelijk Onderzoek KL
Plv. Hoofd Wetenschappelijk Onderzoek KL

4. Hoofd Wetenschappelijk Onderzoek KLu

5. { Hoofd Wetenschappelijk Onderzoek KM
Plv. Hoofd Wetenschappelijk Onderzoek KM

6, 7, 8. Hoofd van het Wetensch. en Techn. Doc.- en Inform. Centrum voor de Krijgsmacht

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